Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Protecting and Promoting the Open Internet	)	GN Docket No. 14-28

REPLY COMMENTS OF NOKIA
D/B/A NOKIA SOLUTIONS AND NETWORKS US LLC

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Reply Comments of Nokia

Nokia herein submits these reply comments pursuant to the Commission's *Notice of Proposed Rulemaking* ("NPRM").[1] As noted in our initial comments, Nokia is a global leader in the areas of mobile broadband network infrastructure and location-based and mapping technologies. Nokia is one of the largest and most successful mobile broadband infrastructure companies in the world with mobile operator customers in more than 100 countries. Our experience gives us unique perspective on the future of mobile networks and the impact of regulatory policy on investment and innovation. Unless otherwise indicated, Nokia's comments are directed at the mobile broadband marketplace and the appropriateness of network neutrality proposals for mobile broadband services.

I. The Cycle of Innovation Requires Enabling Innovation in All Market Segments:

Chairman Wheeler has spoken about the need to preserve an open Internet to ensure that the "virtuous cycle of innovation that has benefited consumers, edge providers and broadband networks" continues.[2] Nokia agrees with, and supports this view, and we note that the Chairman includes within this framework the presumed need for networks to continue evolving in order to support innovation in the rest of the ecosystem. Network evolution requires innovation, which is fueled by the substantial commitment of financial resources regularly made by operators and infrastructure vendors into new research and development. This is a fact that is often ignored in the back and forth of the network neutrality debate. Consider the comments of Public Knowledge et al. in this proceeding in which they state "[w]hile this [treating broadband as a telecommunications service under Title II of the

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[1] In the Matter of Protecting and Promoting the Open Internet, Docket No. 14-28, *Notice of Proposed Rulemaking*, FCC 14-28 (rel. May 15, 2014) ("NPRM").
[2] Statement by Chairman Tom Wheeler on the FCC's Open Internet Rules (February 19, 2014), available at http://www.fcc.gov/document/statement-fcc-chairman-tom-wheeler-fccs-open-internet-rules

Communications Act] means a prohibition against fast lanes and slow lanes, it should also include a prohibition against metered and unmetered lanes."[3]

In effect, what Public Knowledge et al. are seeking is for the Commission to limit wireline and wireless operator flexibility to implement innovative pricing approaches through which a user might have the opportunity to select a plan, speed, or grade of service that meets their particular preferences. Such limitations would also preclude the creation of specialized, or prioritized services through which an operator could offer a guaranteed or heightened quality of service for specific applications and services that depend on low latency for optimal performance. Apart from not representing a market place based on options and consumer choice, this model ignores the critical need for value creation throughout the entire broadband ecosystem, which is a necessary catalyst for the Chairman's vision of a virtuous cycle of innovation to become a reality.

Nokia provides mobile broadband infrastructure to wireless operators around the world. Our experience in the last few years is that critical measures of operator success such as average revenue per user (ARPU) and return on capital employed (ROCE) have been flat or declining in most markets and for most providers including many in the United States.[4] Critics frequently point to profit statements and lament that infrastructure spending has been lower than expected, suggesting that capacity and processing capability can be added easily. Profit, as a measure of revenues less costs, is a poor indicator of the investment environment. Mobile operators will invest in critical capacity and capability, but are unable to do so when the return on that capital deployed into infrastructure does not recover the cost. The ARPU and ROCE metrics are therefore a bell-weather for the investment environment because they are proxy measurements for the ability to monetize marginal investment in the network. This is a key reason that calls to limit the pricing freedom of mobile operators miss the mark. Under a framework in which all traffic must be treated the same, and all consumers purchase their service via pre-packaged plans with no ability to differentiate service to willing users or

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[3] Comments of Public Knowledge, Benton Foundation, and Access Sonoma Broadband. Docket No. 14-28 (filed July 15, 2014).

[4] *See, e.g.*, The Mobile Economy 2013. GSMA and A.T.Kearney at 5, available at http://www.gsmamobileeconomy.com/GSMA%20Mobile%20Economy%202013.pdf.

application and service providers, the entire burden for funding research and development and network construction falls on consumers because they are the one and only source of revenue to the operators.

The limitations of the foregoing approach are readily apparent in the marketplace today. Over the last several years the mobile broadband infrastructure market has undergone significant change. Lower than anticipated spending on infrastructure has led to numerous restructurings and a difficult business environment for many mobile broadband equipment companies. In spite of these difficult circumstances, companies like Nokia continued to invest heavily in the research and development needed to meet 4G network rollouts and to respond to operator demands for solutions like small cells, improved security solutions, and dynamic network management capabilities. Now, the industry is preparing to forge ahead with an aggressive research and development agenda in support of 5G, something that will require significant financial commitments by infrastructure vendors.

Arguments that seek to limit pricing innovation and value creation in the market for mobile data communications are extremely myopic. As noted in Nokia's initial comments, it is possible in our view to allow a multitude of service and pricing innovations directed toward both end-user customers and application and service providers, subject to important safeguards that ensure transparency, choice, and protect against abuse. Doing so has the benefit of creating value at every level of the mobile broadband ecosystem and fueling innovation in each sector that is critical to this ecosystem. Innovation does not *just* occur by and among "edge" companies. If innovation is to be fully enabled in the current market for 4G services and the future market for 5G services, innovation must occur at the network level as well. For this reason, the Commission should reject proposals to enact blanket prohibitions on specialized services and other forms of differentiation and network management.

In terms of how specialized services and other forms of differentiation can benefit the entire ecosystem and facilitate the virtuous cycle of innovation, the Commission should note that the dynamic market for applications depends heavily upon continual improvement in network capacity and performance. Streaming video, online gaming, remote health monitoring and other latency sensitive services are critically dependent on the ability of mobile operators to manage congestion at multiple points in the network to reduce latency and packet loss, among other challenges. With data traffic on mobile networks growing more rapidly than capacity in the networks and available backhaul, substantial innovation is necessary in mobile broadband infrastructure to facilitate improvement in network capability.[5]

Robust research and development in the infrastructure sector requires healthy monetization and investment by operators in network upgrades and improvements. In turn, the evolution of networks through the availability of aggregation technology, small cells, caching and other emerging technology further enables edge companies to develop data hungry applications of increasing sophistication to meet consumer demand. It is important that the Commission recognize that operators and infrastructure providers are a critical element of this virtuous cycle of innovation. Without the innovation in these market segments, innovation is more difficult in all of the others. Nokia therefore recommends that in developing a network neutrality framework in this proceeding the Commission use value creation in all areas of the mobile broadband ecosystem as a guiding principle and objective.

II. Mobile Networks and Services Remain Different

A number of commenters have stated that the Commission erred in the 2010 *Open Internet Order* when it chose to acknowledge that mobile networks and services are different in significant ways from wireline networks. It is puzzling to see Public Knowledge et al. and other parties argue in this proceeding that marketplace developments have fundamentally changed things to a point where the Commission should no longer distinguish between mobile and wireline services.[6] Operators have deployed multiple fourth generation networks and advancing capabilities in the market since 2010; however, it remains the case that mobile networks have a number of technical elements that distinguish them from wireline networks. Mobile networks can be affected by physical obstructions, solar activity, electromagnetic disturbances, and distance to a much greater degree than wireline broadband networks.

[5] LTE's data-hungry apps mean that mobile backhaul must evolve to cope with traffic. Global Telecom Business (May 2014), available at http://www.globaltelecomsbusiness.com/article/3345176/LTEs-data-hungry-apps-mean-that-mobile-backhaul-must-evolve-to-cope-with-traffic.html#.VBEIgBam288

[6] Comments of Public Knowledge, Benton Foundation, and Access Sonoma Broadband, at p. 25. Docket No. 14-28 (filed July 15, 2014).

In mobile networks, regardless of engineering advances and investment in the best technology available, a user can experience reduced data throughput near the edges of a cell. Similarly, where packet loss is extremely rare on wireline broadband networks it can be more common on mobile networks where congested conditions and buffer overflows are more commonplace. These are only a few of the challenges that are more fundamental to cellular technology. It is also important to note that in mobile networks (in contrast to fixed networks) operators have to deal with demand bubbles moving as the users are also moving. Mobile networks have to be engineered to support hotspots of traffic which may pop up for minutes, hours, or on a daily basis due to the migration of people moving through their day. The average person in America has 6 -15 distinct locations per day and mobile networks have to support this level of moving demand.

Given that packet loss and latency impact the performance of many applications and that packet loss and latency are greater challenges to mobile networks, it seems odd that Public Knowledge chose to paper over these and other differences in its call for the Commission to abandon the *Open Internet Order* approach and to now treat wireline and mobile networks under one common, restrictive framework. Nokia hopes that the Commission will consider the input of entities with experience in developing mobile broadband infrastructure and building and operating networks when formulating the rules in this proceeding. We believe that it would be a mistake to impose the level of restrictions implemented on wireline networks in the 2010 order on mobile operators. Reasonable network management practices alone are simply not sufficient to ensure that mobile operators are able to maintain optimal network conditions given the dynamic and fluid nature of cellular networks and the challenges they face. Nokia believes that it is appropriate for the Commission to recognize these challenges and follow a similar path to 2010 when it wisely chose to subject wireless networks to fewer restrictions and to tailor the non-discrimination rule appropriately to permit necessary network management.

III. The Myth of the Bifurcated Internet

The Commission has received a dizzying array of comments suggesting that the mere suggestion of differentiating delivery priority of data packets will result in the destruction of the Internet and the incentive to invest in networks. It is unclear whether commenters offering this dim view of our virtual future cleave to the notion that "data is data" and therefore any disparate treatment, such as prioritizing video packets over email related packets is discriminatory and must be prohibited. Commenters who think data is data appear not to understand that we live now in a world of IP packets and not circuits. Circuits effectively treat all calls equally and as a circuit it means that we reserve a hard capacity for each connection, which obviously is less efficient and reduces network capacity. Internet Protocol networks were built on the assumption that data is not data and that we only create hard capacity for specific uses and only as needed. We prioritize traffic based on managing the flow of discrete packets across the network based on service parameter requirements.

Perhaps those arguing for the express prohibition against prioritization arrangements actually acknowledge that congestion and other network fault issues impact applications and services quite differently such that prioritizing some packets is necessary. In the latter case, the objection appears not to be to prioritization to promote necessary network conditions for services to work properly, rather it is resistance to allowing commercially negotiated fees for prioritization arrangements. Regardless of the intention, it is clear that not all applications and services are impacted in the same manner by network conditions and, further, that some applications and services would benefit from (and may require) heightened service quality via prioritization and other technical methods to function as consumers expect.

Unfortunately, parties in this proceeding, and in the net neutrality debate more generally, have failed to offer the Commission a reasonable basis for adopting a framework that creates value for consumers and all of the entities in the broadband value chain that are essential to the success of the ecosystem. Arguing that prioritization activity should be unrestricted, subject only to limited transparency requirements, is unrealistic. It fails to provide meaningful safeguards to protect against operators advantaging their own affiliated content or services over other entities, or the terms of prioritization falling beyond the reach of new entrants to the application, content, and services market.

At the same time, entities that argue for a strict prohibition against all fee-based differentiation or prioritization arrangements miss the mark. Value creation in all segments of the broadband marketplace is a critical component of maintaining the level of innovation seen in the last decade. As we noted in our initial comments in this proceeding, Nokia believes there is a reasonable, workable framework that the Commission could adopt that would allow for a robust category of specialized services. An entity could pay for an enhanced, agreed level of service quality necessary for its application or service to function at the optimal or preferred level subject to meaningful limitations and safeguards that protect against blocking, throttling, and discrimination.

Nokia believes that consumers would benefit from expanded service options that allow them to align their usage and financial preferences. In the future, as technology evolves it may be possible for mobile operators to introduce a base level plan with a specific data allotment and "best efforts" transmission terms and a range or alternatives that offer larger data allotments, faster speeds, application specific priority, time of day or location based priority and many other dimensions of differentiation. Far from "splitting the Internet in two," this will empower consumers with options to select service plans that meet their very specific needs, at prices that match their available budget. Similarly, as networks are besieged by exponentially increasing traffic from machine-to-machine (M2M) communication, remote telemetry, and the continued emergence of applications with very low network fault tolerance, it will be possible to offer enhanced quality of service options to application and service providers. Not every application or service will require such enhanced service quality, which can be provided in a number of different ways.

Even among the applications and services that may benefit from, and in some cases require, enhanced QoS, not every provider will want to pay for it. This is where the net neutrality discussion usually breaks down for some Internet advocates. They do not appear to deny that applications and services are increasingly sensitive to network performance issues, or that operators can and should take steps to ensure that those applications and services receive the appropriate level of network resources necessary to function properly. Their objection is to charging for the dedication of those resources. Put another way, differentiating traffic delivery options to manage network congestion and ensure performance will *not* "break the Internet," but charging for it will. This is pure sophistry. Fortunately, the Commission has options that will permit healthy innovation in pricing and service delivery that will increase choice and value creation while protecting an open Internet.

Nokia believes that allowing prioritization arrangements that are at the election of the end-user or application/service provider, are non-exclusive such that the same terms are available to others that wish to obtain priority, and are subject to transparency requirements can be a tremendous source of innovation and value creation. The Commission has previously enumerated transparency requirements and proposes to do so again in this proceeding. To the extent that transparency requirements require the disclosure of all commercially relevant information, they can be an important safeguard.[7] Applying this concept of voluntary, transparent, and non-exclusive prioritization to telecommunications networks is possible through a framework of specialized services as noted in Nokia's initial comments. Applications and services that may benefit from, and in some cases require, enhanced QoS are strong candidates for specialized (prioritized treatment). There are a range of emerging technologies including Nokia's application aware radio access network (RAN) technology that offer promising future options to improve the quality of a customer's user experience by increasing throughput.[8] This is just the beginning of advanced technologies to manage networks. Nokia expects the continued emergence of business models to improve the user experience and performance of applications and services. This will allow an array of technical methods to enhance QoS both to end-user customers and application/service providers in the future.

Allowing mobile operators, consumers, and third party application/service providers to develop

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[7] Not all terms or items of information are commercially relevant. Some including the types of technology used to monitor and manage network performance may be trade sensitive and are not essential to either an end-user or application or service provider electing prioritization. An appropriate analogy is to consider the postal service, FedEx or UPS. A consumer wishing to send a parcel enters and is presented with the full range of service delivery options and key terms such as price and expected delivery date. The consumer is not presented with, nor do they require, information on how many modes of transport will be used, which facilities it will be routed through or the treatment of other customers' parcels. Similarly, the terms are available to all customers on a non-exclusive basis and the decision about priority is made by the customer, not the transport provider. It is unclear why communications networks are, or must be, materially different.

[8] *See* Appendix: Nokia Solutions and Networks 3G Application Aware RAN: Creating Value from Application Prioritization (2013).

and select enhanced QoS is not going to “break the Internet” as several commenters have claimed. Quite the opposite. Nokia believes that consumer demand for more data intensive, sophisticated applications that engage large amounts of network resources will likely necessitate enhanced QoS through various types of differentiation. The Commission was careful not to pre-judge and preclude various types of prioritization and differentiation for mobile services in the *Open Internet Order* and should be careful this time as well. The only thing we know for certain about the future of the mobile market is that data consumption and network demands are growing quickly, network performance must keep pace, and significant innovation by operators and infrastructure vendors will be needed in order to enable innovation in the rest of the ecosystem.

Respectfully submitted,

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Appendix A to Nokia Net Neutrality Comments

NSN White paper
November 2013

Nokia Solutions and Networks 3G Application Aware RAN

Creating value from application prioritization

CONTENTS

1. Executive summary: Application differentiation creates added value in mobile broadband

Data usage is growing faster each year and application usage patterns are changing in unpredictable ways. Operators need better methods to cope with the dynamic data consumption unleashed by the presence of smartphones in existing 3G networks. These networks will continue to carry the majority of data traffic over the coming decade. Even as additional spectrum, small cell deployments, network features and optimization techniques help to increase capacity, users expect ever greater quality in their data sessions. High-value subscribers in particular consider data transmission quality to be as important as network coverage or voice quality, according to recent research[1].

The ability to prioritize application traffic dynamically when needed or when it adds value for the user and the service provider in a simple but effective manner creates an opportunity for the operator to move up the data transport value chain beyond being a pipe provider. Existing industry solutions for creating application awareness have limitations that have hindered wide-scale adoption and cannot take advantage of information from the radio access network (RAN) about cell load and radio link conditions. In addition, existing solutions are complex to deploy and cannot react to real-time changes in network and application behavior.

Nokia Solutions and Networks' (NSN's) 3G Application Aware RAN innovation leverages existing core network capabilities to inspect data traffic at the application level while applying policy rules and enforcement. NSN combines core intelligence with RAN awareness of cell load and radio link conditions at the bearer level to create a real-time solution for detecting application data and using it to apply and enforce policy in conjunction with the core and RAN. The inclusion of the RAN is the missing link that gives operators real-time, intelligent control over applications, breaking all the operational limitations that previously prevented networks from introducing application prioritization through transport differentiation. Now operators can create application-specific packages with personalization and targeted pricing to reflect measurable quality.

1. http://nsn.com/news-events/press-room/press-releases/mobile-operators-keep-your-customers-loyal-by-focusing-on-voice-data-quality-1gbperday

NSN Smart Labs results show that per application-level detection is very effective and able to provide significant improvements in data throughput for prioritized services. Smart Labs conducted a series of tests in which diverse popular applications such as web browsing, YouTube, Skype, peer-to-peer (P2P) and file download operated on off-the-shelf Android devices while the cell load varied from no congestion to high congestion. The prioritized application and user experienced the following benefits:

- HTTP web browsing data throughput increased 1.65 times when prioritized in medium-loaded systems and 2.9 times in highly-loaded systems, compared with testing on a best effort basis in a congested cell.
- Response times for web services were improved.
- YouTube video data throughput increased 1.93 times when prioritized in medium-loaded systems and 2.7 times in highly-loaded systems compared with best effort carriage in a congested cell.
- YouTube video stream buffering was reduced or eliminated with faster stream setup.
- P2P traffic scheduling was more flexible.

Operators now have an effective system to offer per application priority at the subscriber level. It is operationally deployable, backwards-compatible to all 3G devices, and provides added, monetizable value for the priority delivery of data services.

2. How do mobile data consumption growth and smartphone usage patterns affect networks?

Mobile broadband networks have been in service for more than a decade but there has been an explosion in data growth and a diversification in usage patterns in recent years. Initial 3G usage models were driven by data cards and what today would be referred to as feature phones, which accessed mainly webpages and email services. The introduction of smartphones in 2007, followed by tablets in 2010 and the arrival of internet-connected devices using machine-to-machine (M2M) communications is all changing the rate of data growth, as well as increasing diversity in the types of data transported over the mobile broadband network.

3. Mobile data usage is set to grow rapidly

Mobile data consumption is growing at an ever-increasing rate. The average smartphone will generate 2.7 GB of traffic per month in 2017, an eight-fold increase over the 2012 average of 342 MB per month. Aggregate smartphone traffic in 2017 will be 19 times greater than it is today, with a CAGR of 81 percent. Two-thirds of the world's mobile data traffic will be video by 2017. Mobile video will increase 16-fold between 2012 and 2017, accounting for over 66 percent of total mobile data traffic by the end of the forecast period.

The Cisco Visual Networking Index (VNI) for 2013 projects that mobile broadband networks will, for the first time in history, carry one exabyte (1 Billion Gigabytes) of data in one month and further predicts mobile data traffic to exceed 12 exabytes by 2018 (Figure 1). Mobile networks are facing a growing possibility of congestion during peak usage hours, despite investments in additional base stations, advanced RF features, and other capacity improvements.

Demand for mobile broadband is closely related to the evolution of device and screen technologies, which are among the areas of the Information and Communication Technology (ICT) industry that are evolving the fastest. It was as recently as 2007 that the first iPhone was introduced with a screen resolution of 320 x 480 pixels. In 2011, the Retina display of an iPad already had nearly twice as many pixels to fill with content. New device form factors such as Google's glasses, which arrived in 2012, continue to drive this evolution. Ultimately only the human eye will limit the amount of digital content that will be consumed by a mobile device. Moreover, these devices not only consume ready-made content. Ubiquitous integrated cameras with high resolution and frame rate are producing exabytes of digital content to be distributed via networks.

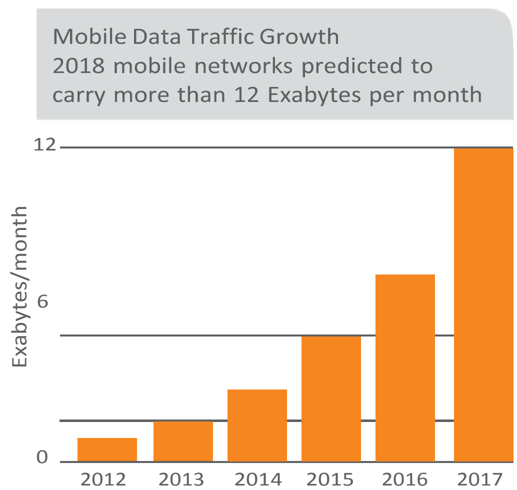

Fig. 1. Cisco VNI 2013 global mobile data traffic growth.

4. Internet usage models are shifting rapidly

While mobile internet network traffic continues to rise, there is a noticeable change in usage patterns. It started with the introduction of the smartphone and is continuing to evolve as subscribers use their devices in different ways. Today, smartphones are used for video streaming, web browsing and gaming, with additional growth expected in file sharing and M2M communication (Figure 2).

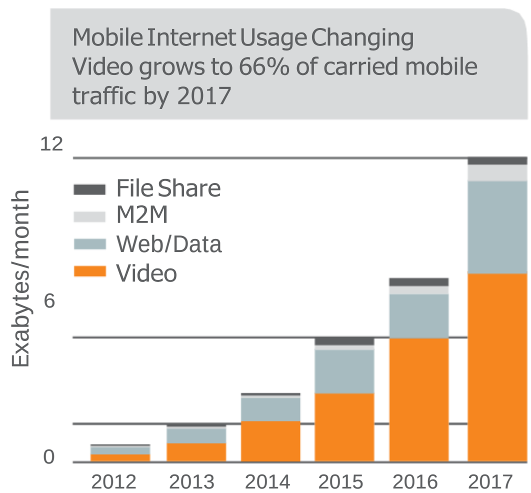

Fig. 2. Cisco VNI 2013 mobile internet usage.

Interestingly, usage models on devices are shifting as different classes of service, content and applications gain or lose prominence. In 2Q 2013, Google Maps was the most used application by users on a monthly basis, followed by Facebook and YouTube (Figure 3). Changes in application popularity by users create significant impact on network traffic owing to large differences in the amount of data transmitted by different applications (consider YouTube versus Facebook, for example).

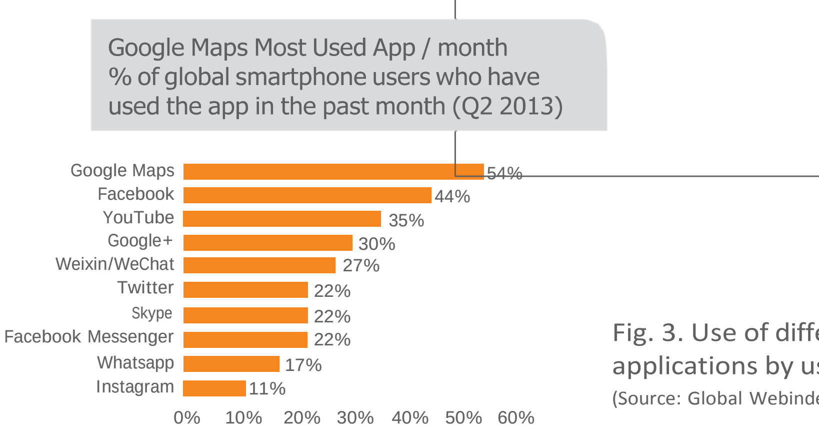

Fig. 3. Use of different smartphone applications by users per month.

(Source: Global Webindex statista Mashable)

5. The evolution of end-to-end data traffic management

How can operators and their customers adjust to the impact of data hungry applications, especially since many data plans have pre-defined usage limits and the popularity of different applications keeps changing? Traditional traffic management and billing models (Figure 4) are inflexible on a per application basis. All types of data traffic are treated equally under a given set of conditions, such as device type (IMEI), subscriber level identity (IMSI), access type (2G to LTE), time of day, data volume and location.

Fig. 4. Current business models treat all traffic equally under given conditions.

6. Vision of QoS versus operational practice

When the wireless industry standardized Quality of Service (QoS) differentiation mechanisms in the 3GPP (Third Generation Partnership Project) more than a decade ago, the idea was to provide per application Access Point Names (APNs) associated with a separate primary bearer (Packet Data Protocol Context, or "PDP context") for each APN supporting different QoS classes. However, it proved impractical to manage multiple APNs per device across the network as the number of applications proliferated. The challenge was compounded by the complexity of 3G QoS and associated device support, which meant that this mechanism was not used in live networks. Instead, many of today's wireless networks have one primary PDP context and change QoS settings for the entire PDP context (and thus for all data traffic within the bearer) on-demand as needed.

The result of treating all traffic types equally owing to the limitations of PDP context-level QoS is a constrained business model, in which single payer models, preferred and paid prioritization don't bring value either to the customer or the service provider because they lack per application-level QoS differentiation.

If application-level differentiation can be enabled, then per application-level management of the Quality of Experience (QoE) is possible, enabling less important data to be delayed and preferred data to be prioritized. New application-level pricing models can be offered thanks to transport being a value added delivery service, rather than a best effort pipe.

7. Business models

Clever, tiered pricing models and bundles containing over-the-top (OTT) services are major tools to help operators combat revenue erosion. This will only become more important going forward as operators explore new models, such as price differentiation by quality and application.

Ultimately, however, there is an increasing danger that the business of being a network operator is changing from a retail model to a utility type of business, with limited room for positive differentiation. Handset vendors and OTT providers are gaining more traction with consumers and it will be harder than ever for operators to establish strong customer relationships in the future as consumers are focused on the latest device and the coolest app. In most markets, customer loyalty is in decline. Consumers are increasingly selecting their operator purely according to price and handset offers.

It’s also clear that the number of cooperation agreements between operators, OTT vendors and other industries will increase significantly, especially in the areas of content delivery. Delivering services in a differentiated and managed way opens up additional personalization and monetization opportunities in partnership with content providers and global content delivery networks (CDNs) by providing a clear value-add to the partners in the value chain and ultimately the end users. A good analogy would be a value-adding logistical service such as a premium postal service offering fast and reliable delivery.

Consider the example of video traffic delivery. The video traffic quality issue can only be rectified by the network operator. The operator owns and operates the only portion of the network between video servers and digital video players that does not carry an explicit Service Level Agreement (SLA). If operators can ensure a better service quality for specific OTT video streams and provide SLAs on those streams that include the journey through the RAN, various parties including consumers might be willing to pay for the value added transport. Content providers want their end users to receive their content at a reasonable quality. There are several potential revenue sources for the operator: the end user paying for “premium” internet TV, the global CDN, the content aggregator and the content provider paying for an explicit SLA.

8. Existing approaches for enabling QoS differentiation per application

The industry has created a number of QoS differentiation solutions in an attempt to solve the need for application differentiation.

These solutions have all seen some level of adoption depending on the needs of the 3G HSPA network operator but they each have limitations that have prevented their use on a large scale.

- Core deep packet inspection/application throttling

  In this case, throttling of the PDP context bearer is triggered by deep packet inspection (DPI), subscription, fair use policy, time of day, the user's initial cell location and a prediction of cell peak hours.

  Limitations: The system is not aware of cell-level loading in real time. To add cell load awareness requires complex system integration (OSS, Policy, GW, DPI) and will be inefficient and inaccurate.

- Network-requested PDP context QoS modification

  Modification of the PDP context bearer is triggered by fair use policy or DPI when usage of the given application is detected.

  Limitations: Modifications impact the whole bearer so all applications are affected by any change. Frequent modifications cause high signaling load in all network elements (GGSN, SGSN, RNC, NodeB).

- Dedicated/per application access point name (APN)

  Higher-level QoS PDP context can be provided by an application-specific APN, which is limited to certain services, domains and operator or partner content.

  Limitations: There is no true application awareness within the PDP context to determine which applications benefit. Typical usage in networks is limited to specific services with policy rules. APN configuration information requires the operator to push terminal configuration parameters to the device and provide support from device software. It's operationally complex to implement, manage and maintain.

- Network-requested secondary PDP context and dynamic application mapping

  Selected applications are routed by DPI in the downlink and user equipment (UE) in the uplink to secondary PDP context in order to provide differential QoS.

  Limitations: This is only supported by LTE terminals and not currently by 3G (or 2G) terminals. It creates challenges in handling a mass of short-lived uplink flows (such as P2P demotion). It creates delay because of the need to activate radio resources when the first data arrives at the dedicated bearer.

Each of these existing solutions solves some problems, but none of them address radio access, which is the best real-time enforcement point for per application QoS differentiation. This must be combined with the core network's control logic enforcement in order to react dynamically to network conditions.

9. Application Aware RAN enables real application differentiation in 3G

The wireless industry is clearly interested in having a solution for per application awareness, but has not been able to implement a comprehensive end-to-end system for 3G QoS differentiation.

NSN has innovated to create RAN application awareness, which works across all existing HSPA-capable terminals to allow operators and their customers to prioritize important and specific data traffic flexibly, without operational complexity.

NSN's Application Aware RAN solution (Figure 5) uses application rules and subscriber-specific QoS policies from the Policy Control and Rules Reference Function (PCRF) combined with DPI at the Policy Control Enforcement Point (PCEF) for the identification of differential QoS data traffic combined with RAN-based application awareness. This enables fast radio scheduler reactions to changing cell loads and policy requirements.

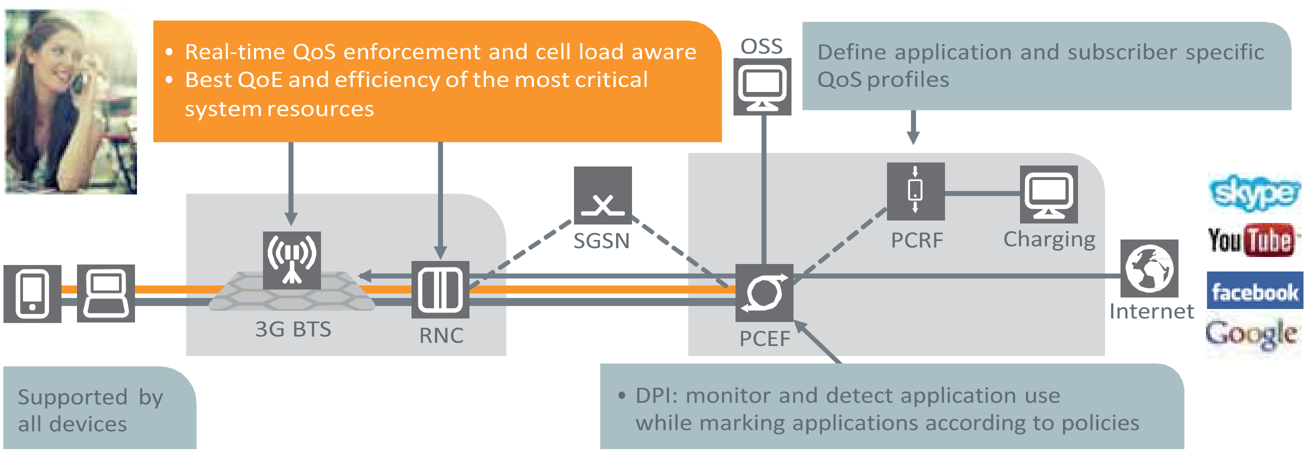

Fig. 5. NSN Application Aware RAN end-to-end system approach.

10. Impact of Application Aware RAN QoS on user QoE

In order to benchmark the efficacy of the NSN Application Aware RAN solution, a series of lab tests were conducted in the NSN Smart Labs using a 3G HSPA network with commercially available HSPA Android-based smartphones. Note that NSN's Application Aware RAN solution is network-based, dynamic cell-load aware and terminal-independent, so it supports all HSPA devices. Five different common smartphone activities were tested, including web browsing, file download, YouTube, P2P torrent and Skype.

The test setup is shown in Figure 6. Note that real-world results may vary from lab environment results.

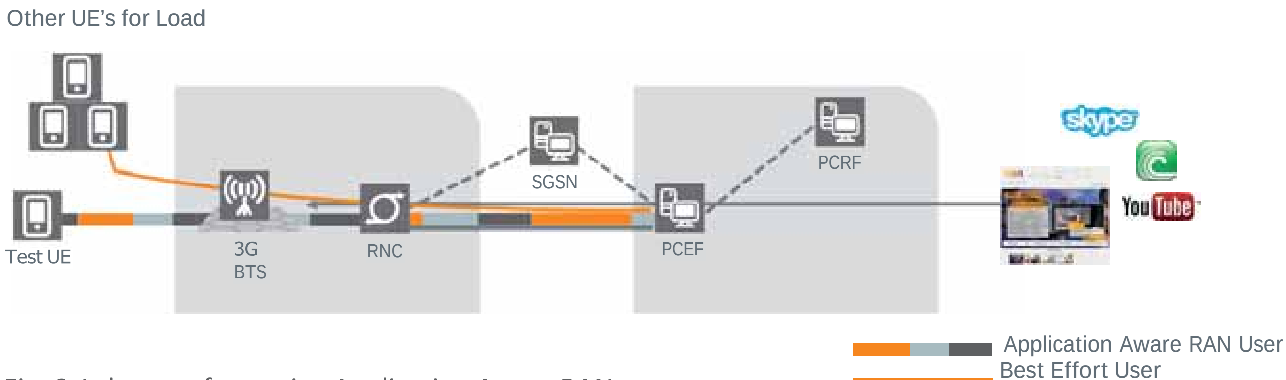

Fig. 6. Lab setup for testing Application Aware RAN.

11. The test cases explored

The researchers looked at five types of applications commonly used in an HSPA network under varying levels of load. They tested the impact of per application priority setting versus no priority as a best effort application.

Additional scenarios explored real-world user behavior, which typically involves using multiple applications simultaneously on one device with priority-setting as the network load varies.

Finally, they tested the selective prioritization of applications on a device in preference to other applications on the same device.

Table. 1. Description of test cases to verify the impact of Application Aware RAN.

Test Scenario	Test Decription		
Unloaded system	Single application (web browsing, file download, YouTube, P2P torrent and Skype) with PRIORITY		
Medium cell load	Single application with NO PRIORITY (best effort)	Single application with priority	Multi-application with single application priority
High cell load	Single application with NO PRIORITY (best effort)	Single application with priority	Multi-application with single application priority

12. Application Aware RAN

12.1 Application Aware RAN priority greatly improves web browsing performance

NSN Smart Labs testing of prioritized HTTP web browsing with Application Aware RAN shows significant performance improvements resulting in higher user satisfaction for prioritized versus non-prioritized (best effort) sessions during periods of congestion.

Test results showed remarkably improved service quality for a user with web browsing priority under different load conditions:

- Under medium cell load with prioritization, throughput increases from 4.1 Mbps to 6.8 Mbps or 1.65 times compared with tests with no priority as a best effort application.
- Under high cell load with prioritization, throughput increases from 1 Mbps to 2.9 Mbps or 2.9 times compared with tests with no priority as a best effort application.
- All tests show a general improvement in response times for web services.

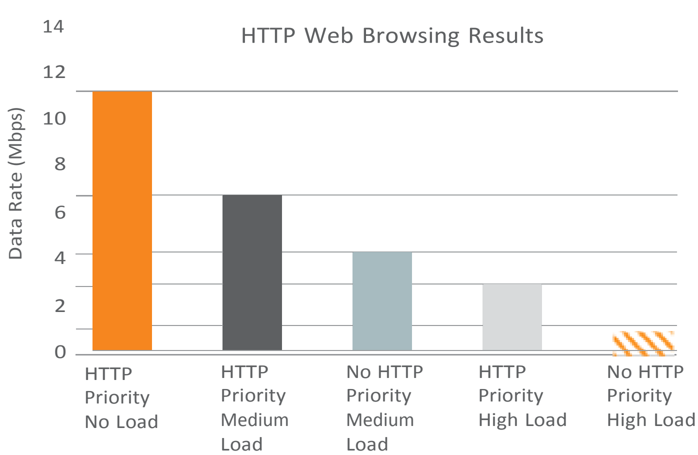

Fig. 7. HTTP browsing results, prioritized vs. non-prioritized (best effort).

12.2 Application Aware RAN priority boosts YouTube video performance

If Application Aware RAN prioritization can improve web browsing for selected users during periods of congestion, what effect can it have on demanding video sessions? NSN Smart Labs applied application priority to a user streaming a 30 second, 720p YouTube video clip to an off-the-shelf Android device. Cell-level congestion conditions were varied from no load to high load using additional devices. A performance comparison of YouTube sessions with application priority and with no application priority (normal best effort data) was conducted.

Application Aware RAN created significant performance improvements in data throughput at times of congestion for a user with a prioritized YouTube service (Figure 8):

- Under medium cell load with prioritization, throughput increases from 3.2 Mbps to 6.2 Mbps or 1.93 times compared with tests with no priority as a best effort application.
- Under high cell load with prioritization, throughput increases from 1 Mbps to 2.7 Mbps or 2.7 times compared with tests with no priority as a best effort application.
- The user with a prioritized YouTube service also experiences faster server access, making it quicker to set up a video stream. More importantly, when the cell experiences high load, video buffering times are substantially decreased.
- YouTube data is successfully detected and prioritized, while other application data continues as best effort traffic.

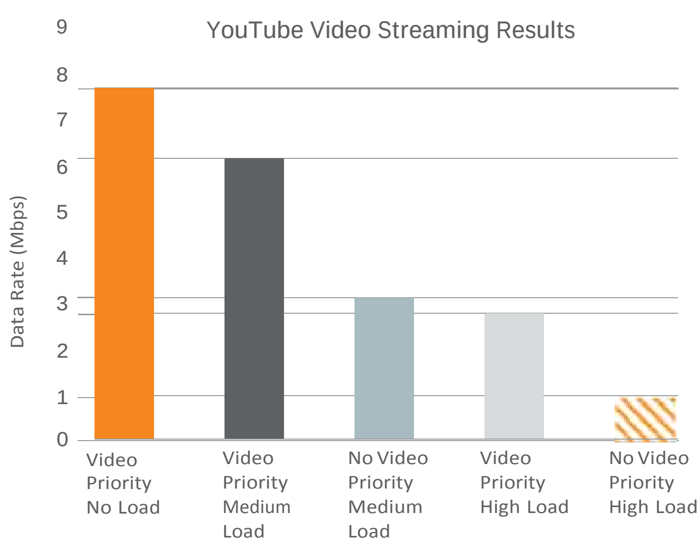

Fig. 8. HTTP YouTube video session results, prioritized vs. non-prioritized.

13. End-to-end QoE measurement with performance manager and service quality manager for priority services

Ensuring service quality for more demanding applications such as YouTube requires Operational Support Systems (OSS) to let the operator know that the enabled priority plan is working as expected.

NSN has designed OSS support to monitor application performance in management systems, with an overview and drill down support available for Application Aware RAN. Operators can monitor high-value applications within the network 24/7, with views of differentiated application throughput at the cell level and root cause analysis of service degradation, if it occurs. With the integrated measurement capability from NSN's management service, operators can see QoE analysis with easy reporting of differential throughput for users and applications.

Performance Management for Precise following of application priority classes
Know what you deliver to meet marketing promises & ensure great user experience

Measure active application throughput per SPI using End-user experienced DL throughput

Monitor application performance using Performance Manager/Service Quality Manager

- Holistic view or drill down to SPI level
- View differentiated app throughput easily - per app priority class & cell

Fig. 9. NSN performance management systems for application monitoring.

14. Find out more

Other test cases were conducted on P2P torrent traffic priority, HTTP file download, Skype, multi-application priority and differential priorities for applications on the same device.

Contact NSN for more details and the results of the other Smart Labs tests for Application Aware RAN for 3G.

15. Abbreviations

3G	Third generation cellular
3GPP	Third Generation Partnership Project
APN	Access point name
BE	Best effort
CDN	Content delivery networks
DPI	Deep packet inspection
NB	NodeB
GBR	Bearer with reserved bitrate resources
GGSN	Gateway GPRS support node
GW	Gateway
HSPA	High-speed packet access
HTTP	Hypertext Transfer Protocol
IMSI	International Mobile Subscriber Identity
IMEI	International Mobile Equipment Identity
LTE	Long Term Evolution
NW	Network
OTT	Over-the-top
OSS	Operational support systems
PDP	Packet Data Protocol
P2P	Peer-to-peer
PCEF	Policy Control Enforcement Point
PCRF	Policy Control and Rules Reference Function
QCI	Quality Class Indicator
QoS	Quality of service
QoE	Quality of experience
RAN	Radio access network
RNC	Radio Network Controller
SGSN	Serving GPRS Support Node
SLA	Service Level Agreement
UE	User equipment

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